NATIONAL HYDROLOGY PROJECT

Online Training on "Use of CORS Network and Height by Geoid Model"

07th June, 2022

At

Geodetic & Research Branch, Survey of India. Dehradun
(DEPARTMENT OF SCIENCE & TECHNOLOGY, GOVT OF INDIA)

Project Director Office,
National Geo-Spatial Data Centre
Hathibarkala Estate
Dehradun – 248 001
(Uttrakhand)

CONTENTS

PREFACE

National Hydrology Project Known as NHP-III is a World Bank assisted project and coordinated by Ministry of Jal Shakti. The aim of the project is to improve the planning, development and management of water resources as-well-as flood forecasting and reservoir observations in real-time.

Under NHP-III, SOI is providing updated digital topographical Geo-database and DEM of 3-5m accuracy of around 8,35,742 Sq. Km. area as–well-as DEM of 0.5m accuracy of approximately 71,203 Sq. Km. area.

Under NHP Survey of India has established a network of Continuously Operating Reference Stations (CORS) in Uttar Pradesh and Uttarakhand which is capable of providing Real Time Positioning Service through RTK/NRTK. During various discussions at NPMU and with other State Implementing Agencies (IAs), it was felt that there is a need to create awareness among officers and staff of IAs, specifically regarding use of Continuously Operating Reference Station (CORS) for precise positioning at any place and Geoid Modeling to deduce orthometric height using GNSS observations. Hence, an online training programme of 01 day on "Use of CORS Network and Height by Geoid Model" for NHP field work was envisaged and conducted on 07th June, 2022 in which 09 participants from various Implementing Agencies participated.

The response of training on "CORS Network and Height by Geoid Model" has been very encouraging and there is a demand for more training on the subject.

We also expressed extreme gratitude to Surveyor General of India for his continuous support for NHP in general and conduct of training in particular. Sincere thanks due to Shri Neeraj Gurjar, Director, G&RB, Shri Avanish Kumar, Dy. Superintending Surveyor, Shri Bhaskar Sharma, Officer Surveyor, Shri Ravi Prakash, Officer Surveyor and Shri A.P. Mahajan, Officer Surveyor for taking lectures at our request and staff of G&RB, Dehradun for conducting the training. Thanks are also due to Col S.K. Dwivedi, Nodal Officer, NHP & Director NGDC, Shri Ajay Kumar, OS and other officers & staff of NGDC for organizing the training as-a-whole.

At last but not the least we are extremely thankful to NPMU for their continuous guidance and state IAs for deputing various officers to participate in the training.

(S. V. Singh)
Project Director
National Hydrology Project-III

Training Schedule

Time	Topic	Lecture
07-06-2022		
15:00 Hrs	Use of CORS Network	Sh. Avanish Kumar, DSS, G&RB
15:30 Hrs	Height by Geoid Model	Sh. Bhaskar Sharma, OS, G&RB

List of participants attended the training

Sl No	Name (Mr/Ms.)	Designation	Email-ID	Mobile No	Department/ Implementing Agency
1	Pinnapareddy Tejasri	Assistant Executive Engineer	shanmukha.pp@gmail.com	8886149968	Water Resources Department, Govt of Andhra Pradesh
2	Ashish Kumar Vijay	Deputy Engineer	ashishvj087@gmail.com	7435885325	Water Resources Department , Govt of Gujarat
3	Shruti Halli	Research Assistant	shruthi.shivaganga@gmail.com	6363209161	Water Resources Department, Govt of Karnataka
4	Jagadish Prasad Patra	Scientist D	patra.nih@gmail.com	9870784572	National Institute of Hydrology (NIH)
5	Abhijit behera	Research Assistant	Abhijitbehera91@gmail.com	8847845575	Ground Water Development , Govt of Odisha
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7	M Abdul Rahman	Assistant Engineer	abrahwrd@gmail.com	9585688734	Water Resources Department, Govt. of TamilNadu
8	Jyoti Gaur	IT Specialist	gaurjyoti82@gmail.com	9044577701	Irrigation and Water Resources Dept., Govt of Uttar Pradesh
9	Anita Mandal	Data Base Specialist	mandal.anita@gmail.com	9026926502	Irrigation and Water Resources Dept., Govt of Uttar Pradesh

Presentations

PRESENTATION ON

USE OF CORS NETWROK

By
Shri Avanish Kumar,
Dy Superintending Surveyor, G&RB

CONTINUOUS OPERATING REFERENCE STATIONS (CORS)



Introduction:

- **Control points** are primary requirement for any surveying and Mapping activity for Nation Development purpose.
- A control point is any point on the surface of the earth whose Latitude, Longitude and Height OR Easting, Northing and Height is known with reference to certain datum.
- A **datum** is a reference from which spatial measurements (Latitude, Longitude and Heights) are made.

- **The Control Survey generally classified as:**
  - Horizontal Control: Easting, Northing OR Latitude, Longitude Datum is Ellipsoid (WGS-84 Ellipsoid)
  - Vertical Control: Height, the Datum for Height Control is MSL or Geoid.
- **METHOD FOR PROVIDING HORIZONTAL CONTROL:**
  - CONVENTIONAL METHOD:
    - Triangulation: Carried out in hilly terrain
    - Trilateration: Carried out in hilly terrain
    - Traverse: Carried out in Plane area
  - MODERN METHODS:
    - GNSS STATIC Survey
    - GNSS RTK OR NRTK Survey

Background

- **Status of Horizontal Control in India:**
  - **2500 Ground Control Points (GCPs) in India: 30 – 40km apart**
  - **Provision of Control by GCPs: Static GNSS Surveys and Post Processing of data**
  - **It was a Passive System**
  - **Long Observation duration and post processing of data required.**
  - **It is time consuming**
  - **Not Suitable for present days users requirements**
- **Solution to the Problem:**
  - **Requirement of Active GNSS Stations CORS & Network RTK**
  - **Few Minutes Observation is required for cm level accuracy**

OBJECTIVE:

- **To replace the conventional time consuming GNSS static survey technique by effective & efficient use of Network RTK technique for Large Scale Mapping, SVAMITVA project, NHP and NMCG project & and various other developmental activities by establishing CORS Infrastructure.**

What is a CORS Networks?

- **Continuously Operating Reference Stations (CORS) are geodetic quality GNSS receivers and antennas that are permanently installed at a Reference Station (RS) having very accurately pre-determined coordinates.**
- **These Reference Stations collect GNSS data continuously, and transmit data via Internet to a Central Server.**
- **At the server, the data is archived for future use, and made available for download by any user.**
- **The incoming data is also processed at the server to generate corrections which are made available to users over the Internet to users in real-time.**

CORS ESTABLISHMENT PROCESSES

- CORS Site Selection
- Permission to build CORS Monument from local Authorities
- Construction of CORS Monument
- Installation of GNSS Instruments and other accessories (Power, Communication etc.)
- Establishment of CORS Control Centre
- Processing of CORS data (72 Hrs. GNSS data) using scientific software (Bernese 5.2) in order to derive highly precise coordinates of CORS.
- Validation of accuracy of NRTK Results obtained using CORS Network
- Finally Users Registration for use of CORS Network for Surveying and Mapping Applications

Component of A CORS Network

1. Continuous Operating Reference Station (CORS)

Continuous Operating Reference Station (CORS)

- Geodetic quality GNSS receivers and antennas are permanently installed at a Reference Station (RS) having very accurately pre-determined coordinates.
- These Reference Stations collect GNSS data continuously, and transmit data via Internet to a Central Server (Control & Processing Centre).
- A CORS station requires power to operate GNSS Receivers, for which a solar panel along with electric connection is installed at each CORS site for 24x7x365 data collection.
- The Communication between GNSS receiver and the Control Centre, is established by ADSL/Broadband connection installed at each CORS site along with automatic swapping dual SIM GSM/GPRS facility for 24x7x365 data transmission.
- Met sensors are also installed at few CORS sites to collect meteorological data for various scientific studies.
- Highly precise coordinates of each CORS sites are derived by processing of 72 hours GNSS data using scientific software Bernese 5.2.

CORS COMPONENTS

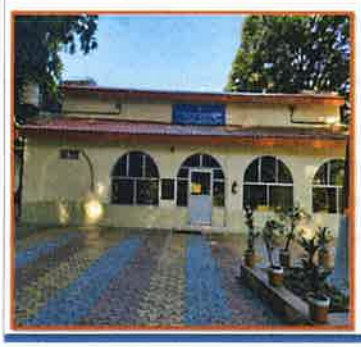
CORS Site

Different components of CORS Site

Component of A CORS Network

2. CORS Control and Processing Center

Situated in Geodetic & Research Branch of Survey of India Dehradun



CORS Control and Processing Center

- CORS Control Centre is equipped with high end servers and GNSS data processing software.
- The software process the incoming GNSS data from CORS sites and generate the corrections in real time for the users (roving receivers) working within the CORS network.
- The Control Centre then generates corrections and transmit to rover in Real time and with an accuracy better than a few centimeter.
- CORS Control and Processing Center is Situated in Geodetic & Research Branch Dehradun.
- Control Centre also has redundant power and communication for its operational 24x7x365 basis.
- The Control Centre is fully secure and safe. For its safety 6 Nos. of CCTV installed in the Control Centre to monitor the security aspects of the CC.

Component of A CORS Network

3. GNSS Rover

A GNSS Rover doing NRTK survey work with reference to CORS network.

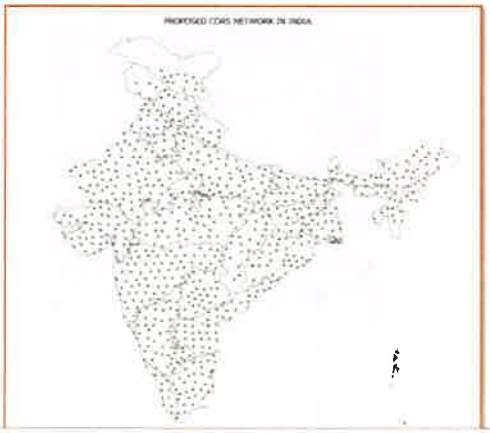
Within few minutes observation at rover end the accurate coordinates of Rover can be obtained, i.e. Latitude, Longitude and ellipsoidal height.

Survey Work With Reference to CORS with NRTK

Officers performing Survey Work with Reference to CORS in Uttar Pradesh with NRTK corrections.

Proposed CORS Network in India

An Active Control Network About 960 CORS



Achievements

STATE	INSATALLED
PUNJAB	16
HARYANA	19
HIMANCHAL PRADESH	6
KARNATAKA	49
MADHYA PRADESH	90
MAHARASTRA	77
RAJASTHAN	85
DELHI	1
UTTAR PRADESH	66
UTTARAKHAND	15
JAMMU	15
JHARKHAND	10
KERALA	8
GUJRAT	5
TELENGANA	1
ODISHA	9
CHATTISGARH	28
TOTAL	500

CORS NETWORK in UP & UK
74 CORS

CORS PRODUCT & SERVICES

- **The following Product & Services are available for the Registered users**
  - **NRTK service with an accuracy of 3 to 4cm for users in Real Time**
  - **CORS GNSS Data for static survey users and scientific community**
  - **DGNSS service with an accuracy of 30 to 40cm for GIS users**
  - **Online Processing Service for the users who do not have much exposure in post processing of GNSS data**

APPLICATIONS OF CORS

- LARGE SCALE MAPPING PROJECT
- SVAMITVA: LARGE SCALE MAPPING OF RURAL INDIA
- GROUND DATA & DEM VALIDATION IN NHP AND NMCG PROJECT
- GEOID MODELLING
- CRUSTAL MOTION
- GEO-LOCATION OF AERIAL MOVING PLATFORMS
- AND MANY MORE

Thank you for your attention

Please visit our website: www.cors.surveyofindia.gov.in to register and download Standard Operating Procedure.

PRESENTATION ON

GRAVITY & GEOID MODELLING

By
Shri Bhaskar Sharma,
Officer Surveyor, G&RB

Gravity & Geoid Modelling

Recent Developments & Future Prospects

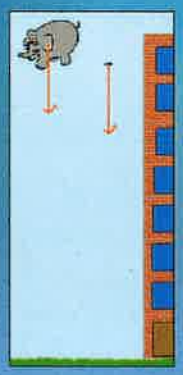
Geophysical Wing
Geodetic & Research Branch
Survey of India

GRAVITY

- The Knowledge of Gravity Field is very important in the study of our globe. If we know the gravity anomalies as we know in many cases we can determine the figure of the earth and shape of the Geoid.
- If the earth were in equilibrium its figure would be close to an ellipsoid of revolution and gravity field around it will be regular. But due to irregularity in the Geoid and Ellipsoid there are deviation between the two.
- Although the deviations are small but may range upto 100 meters.
- In G & R B, Geophysical Wing which was earlier known as 19 Party is responsible for geophysical measurements in the country.

GRAVITY

- Gravitation is the force of attraction between two bodies, such as Earth and our body. The strength of this attraction depends on the mass of the two bodies and distance between the two.
- A mass falls to the ground with increasing velocity and the rate of increase is called gravitational acceleration, 'g' or gravity.



Variation in the value of 'g'

- 'g' is minimum at equator and maximum at poles.
  - Shape of the earth
  - Axial rotation of the earth

Principal variation in gravity with Latitude from Pole to Equator ranges from 983 to 978 gals.

- 'g' decreases on going above the surface of the earth.
- 'g' decreases on going below the surface of the earth.

There is decrease of about 1 mgal per 3 meter. Above sea level.

In addition there are random variations.

The Centrifugal force caused due to rotation of earth is the main cause of the variation in the strength of the gravity field from equator to poles.

Flattering at polar regions also is the reason for increase in the gravity field at Poles.

UNITS OF GRAVITY

The International Unit of Gravity is 'Gal' after the name of Galileo who first measured gravity on earth.

- 1 Gal = 1 cm/Sec²
- 1 Gal = 1000 m Gal
- 1mGal = 1000 micro Gal (μGal)

Computation of various Gravity Anomalies

(a) Free air anomaly
(b) Modified free air anomaly

(b) Bouguer anomaly
(c) Modified Bouguer anomaly

- All the gravity values are based on the IGSN-71 gravity datum.
- The entire gravity anomaly computations are based on GRS-80 terms.

In India about 56 Standard Gravity base Stations have been established almost on all the Air ports in the country. The Datum for all these stations was Palam Airport, New Delhi.

KINDS OF GRAVITY METERS IN USE

Relative Gravity meters:

Relative Gravity meters measure relative changes in 'g' between two locations. This is based on the principle of "COMPENSATION OF GRAVITY BY THE ELASTICITY OF A SPRING".

These relative measurements are tied up with the standard gravity network which is ultimately connected to absolute gravity net work.

Absolute Gravity meters

Absolute Gravity meter measures the actual value of g by measuring the speed of a falling mass. The precision is 0.01 m Gal to 0.001 m Gal. But they are heavy, bulky and expensive.

GRAVIMETERS USED IN SOI

Although various Pendulum apparatus were used at different period before 1946.

However following Gravimeters were introduced at different time :-

Relative Gravimeter	Reading Resolution
• Frost Gravimeter	±0.1mgal
• Worden Gravimeter	±0.1 mgal
• Lacoste & Romberg (G model)	±0.01mgal
• Lacoste & Romberg (D model)	±0.005mgal
• Scintrex CG3M Digital Gravimeter	±0.001mgal
• Scintrex CG-5 Digital Gravimeter	±0.001mgal
• Scintrex CG-6 Digital Gravimeter	±0.001mgal

Absolute Gravimeter

•Micro-G Lacoste A10 Absolute Gravimeter ±0.0001mgal

Lacoste Model 'G'

SCINTREX CG-3M

SCINTREX CG-5

SCINTREX CG-6

ABSOLUTE GRAVIMETER A10

Different kinds of Gravity Survey

- *10 km X 10 km Gravity Meshwork for Geoid Modelling.*
- *1 to 5 km dense mesh for various developmental projects.*
- *Extra Departmental projects.*
- *Bench Marks of all High Precision leveling lines.*
- *Repeat gravity observation for seism tectonic studies.*

HEIGHT

- *We have 2 main categories of Height references:*
  - *Orthometric Height*
  - ***Ellipsoidal Height***

- *The Orthometric Height or Geodetic Height is the vertical distance from a location on the Earth's Surface distance to the geoid (blue surface in the Pic). Because the earth geoid is set a the level of the average sea level it is often called the elevation/Height at Mean Sea Level (MSL).*
- *The **Ellipsoidal Height** of that same point of the Earth Surface is the vertical distance from that point to the ellipsoid (orange surface in the Pic).*

Geoidal Undulation is the distance from the surface of an ellipsoid to the surface of a geoid measured along a line that is perpendicular to the ellipsoid.

Geoid Model

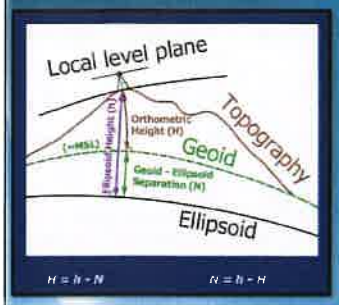
If the earth were in equilibrium its figure will be close to an ellipsoid of revolution and gravity field around it will be regular. But due to irregularity in the shape of Geoid and Ellipsoid there are deviation between the two. Although the deviations are small but may range up to 100 meters.

The primary reference for heights is the 'Geoid' which may be defined as:

An equipotential surface of the Earth's gravity field which corresponds most closely with 'mean sea level (MSL)' in the 'open oceans', ignoring the semi-dynamic effects of ocean currents.

It extends continuously through the continents and, as such, is commonly used as the datum for topographic elevations in many countries. In simplest terms it is a datum which conforms to the laws of physics which says water must flow from higher potential to lower potential.

https://www.youtube.com/watch?v=q65O3qA0-n4

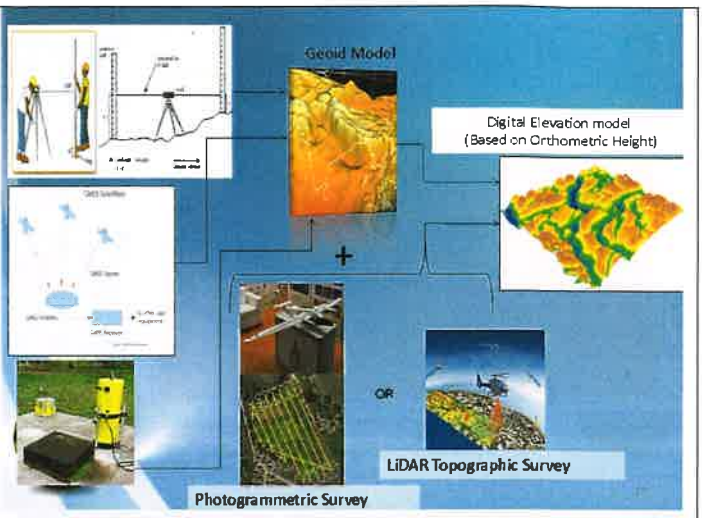


The ease & ability of GNSS (Global Navigation Satellite System) to derive fairly precise and accurate horizontal positions (x,y) is well known and fully established but derived ellipsoidal height (h) is not suitable for practical purposes. GPS/GNSS are based on a mathematical Surface called ellipsoid which do not obey the water flow criteria as per the laws of physics.

Geoid Model (N) relates GPS / GNSS derived heights (h) with Orthometric (Physical) heights (H) using the relationship

$$N = h - H$$

it facilitates direct conversion of ellipsoidal heights in to Orthometric heights.



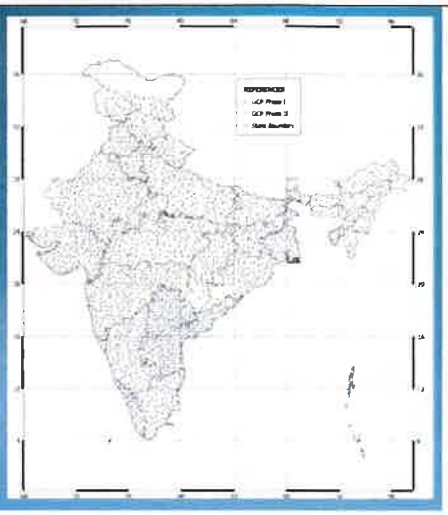
Data available with Survey of India

Gravity Coverage

About 29000 observed gravity points

GCP Network

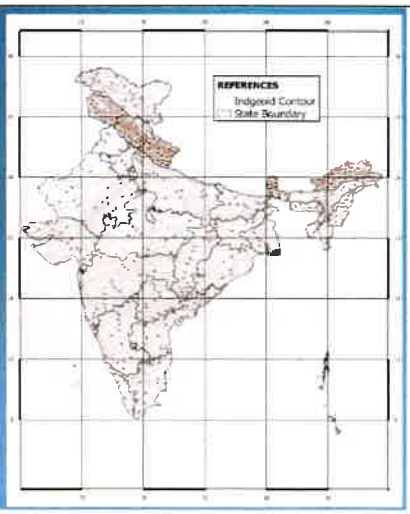
About 2520 observed GCP points

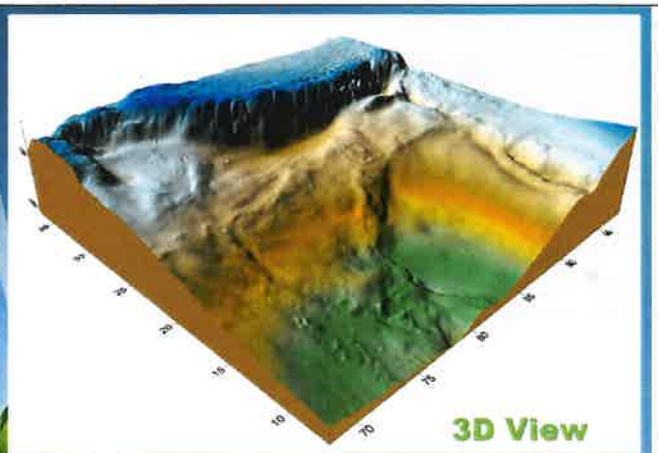


Spirit Levelling Data

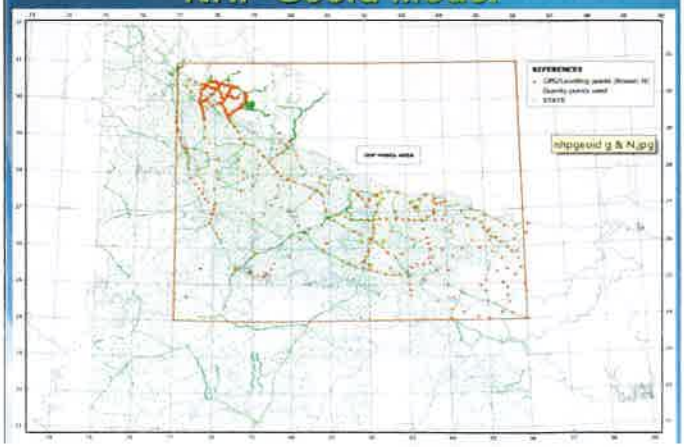
About 66000 km of levelling in fore & back direction has been completed.

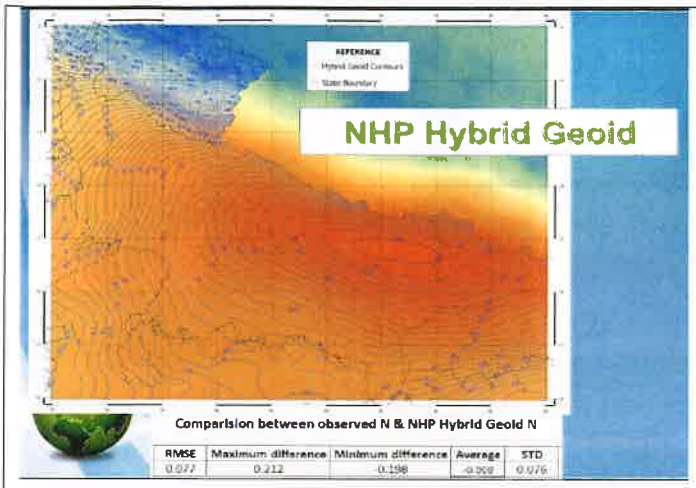
IndGeoid





NHP Geoid Model





Comparision between observed N & NHP Hybrid Geoid N

RMSE	Maximum difference	Minimum difference	Average	STD
0.077	0.212	-0.198	-0.009	0.076

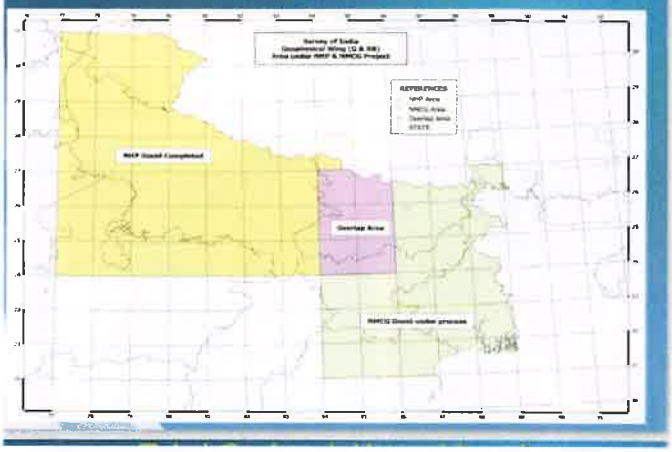
Improvement of Accuracy due to Development of NHP Geoid when Compared with IndGeoid

Geoid	No of Check points	RMSE (m)	Std. Dev. (m)	Mean (m)	Min Diff (m)	Max Diff (m)
IndGeoid	151	0.146	0.144	0.024	-0.279	0.549
NHP Geoid	151	**0.077**	0.076	-0.009	-0.198	0.212

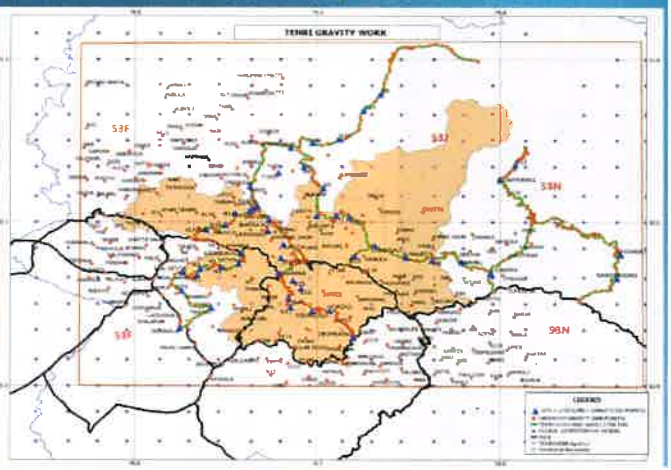
Note :- Accuracy improved by about 47% with respect to IndGeoid result.

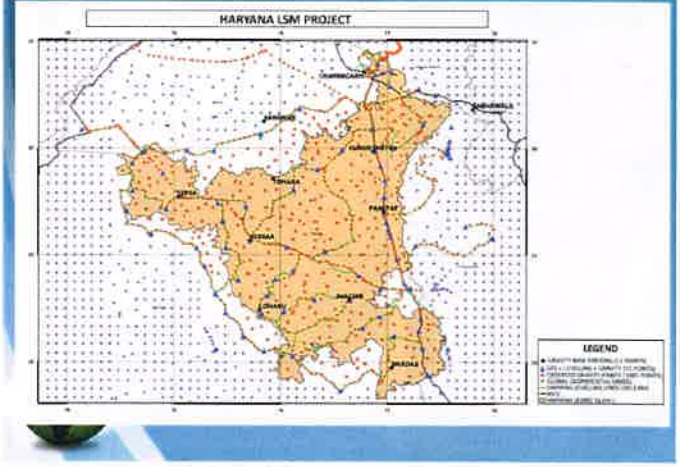
NMCG Geoid Model

NHP NMCG Hybrid Geoid



Tehri Garhwal, Uttarakhand

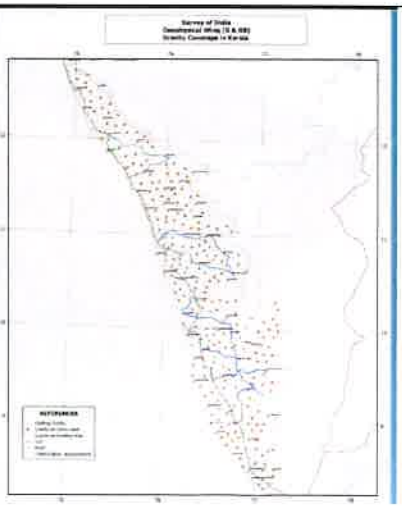




GOA

Ongoing Projects

Flood Level Marking Project, Kerala



Ongoing Projects

TELANGANA

RECONNAISSANCE & SITE SELECTION

i. To find out the ellipsoidal height of a station, a network is to be formed with respect to two GCPs (either Phase-I or Phase-II) established under GCP Library Project in India, in such a way that selected Bench Marks & GCPs form an ideal figure for GNSS observations in each exercise.

ii. Permanent Nature Standard Bench Marks (SBMs) may be selected viz. Type 'B', Type 'M' Type 'P' etc. from the Leveling Line of RIVD.

iii. Reference Pillar to Type 'B' Bench Mark should not be taken for GNSS observations.

iv. If GCP is found destroyed another suitable nearby GCP should be reconnoitered (according to map) and selected for GNSS Exercise.

v. The suitability nature / information (intact or shifted/ disturbed/destroyed) of selected SBMs/GCPs must be maintained. This information must be intimated to GB.RB, Survey of India.

vi. The selected points should have a sky clearance of 15° for GNSS Observations.

vii. The accuracy of observed ellipsoidal height using GNSS observation mainly depends on the observation site that should be free from obstruction. Selected points should not be near reflecting surfaces like Water Bodies, Chimneys, High Power Transmission Lines, Cellular Towers, Microwave Towers etc., which create multi path and induce errors in GNSS observations.

viii. All Station's photograph must be taken for future reference. A sketch/diagram of selected SBMs/ GCPs must be drawn neatly with surrounding details.

ix. Description should be written by mentioning complete & clear information of surrounding objects/features detail of SBMs/GCPs with road connectivity from nearest Village/Town/City as well as the names of Tehsil & District etc.

GNSS OBSERVATION

i. Before starting GNSS Observations make clearance around the station by cutting near by bushes, chopping of branches of trees.

ii. A Site Log Form for each station and for each set of observations should be maintained separately along with a GNSS Observation Register.

iii. All the information, given in Site Log of observed station should be maintained in GNSS Observation Register.

iv. Site Log Form for each GNSS observation on GCP, should have the information viz. Name of the GCP, Date of Observation, Starting and Closing Time, Height of Antenna, Receiver & Antenna Nos. etc., should be entered on appropriate place.

v. Three measurement of Antenna Height should be taken at 120° apart with measuring rod available with the instrument, a photograph clearly showing height of Antenna, coinciding with the edge point of antenna on measuring rod, to be taken & saved.

vi Antenna Height will be measured in meters as well as in inches.

GNSS POST PROCESSING

i. The GNSS data must be downloaded and processed using suitable processing software.

ii. The processing must be done with respect to at least two GCPs (either Phase-I or Phase-II) established under GCP Library Project in India.

III The known coordinates of the GCPs must be obtained from Survey of India before processing the observations.

Iv All the information, given in Site Log of observed station should be used in GNSS processing.

v It is also suggested that, the Precise ephemeris may be used while processing the GNSS data.

vi After processing all the standard errors, RMSEs must be well within the permissible limits.

Conclusion

- As it is clear that for a large projects like NHP, NMCG, LSM, Swamitva, etc., the usefulness of a Geoid Model is immense.
- It has been clearly established that the high resolution data over an area increases the accuracy by nearly 47% (in case of NHP).
- Similarly, it has been observed that the NMCG and other Geoids will also reduce the uncertainty by huge margin therefore making the end product to meet the project requirements.
- In view of the encouraging results obtained as a result of the unparallel efforts of hundreds of man hours of officers, surveyors and unskilled labours, it can be concluded that a High Resolution Pan India Geoid Model will support the various projects of national importance and will make India 'Atmanirbhar' by having its own Geoid model developed by its own human resource.
- To achieve this goal, more data collection for development of more precise IndGeoid is already under way at departmental as well as under various projects.
- It will definitely facilitate GNSS user community to derive faster & cheaper Orthometric heights.

Thank you!

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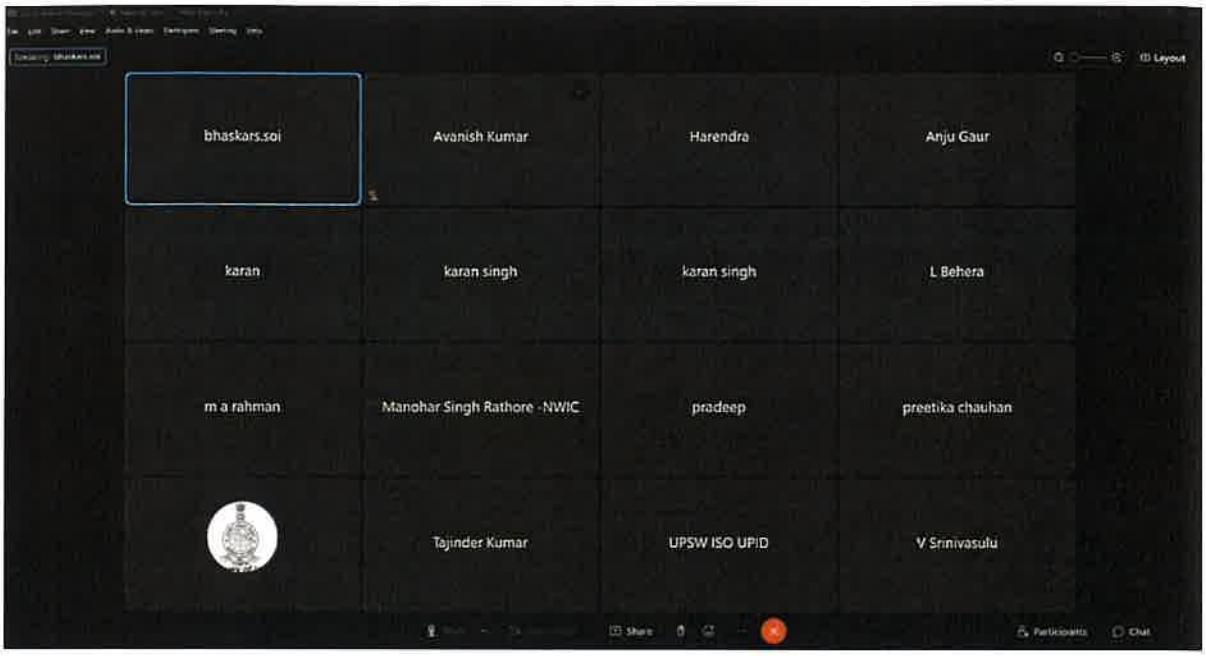
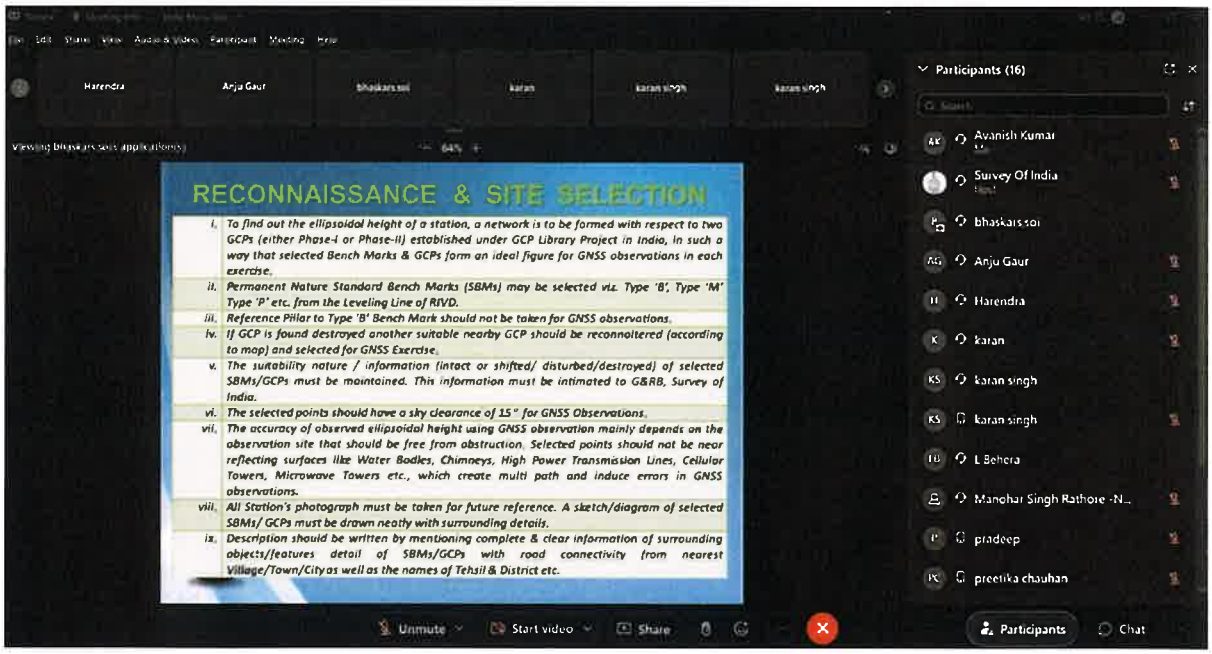
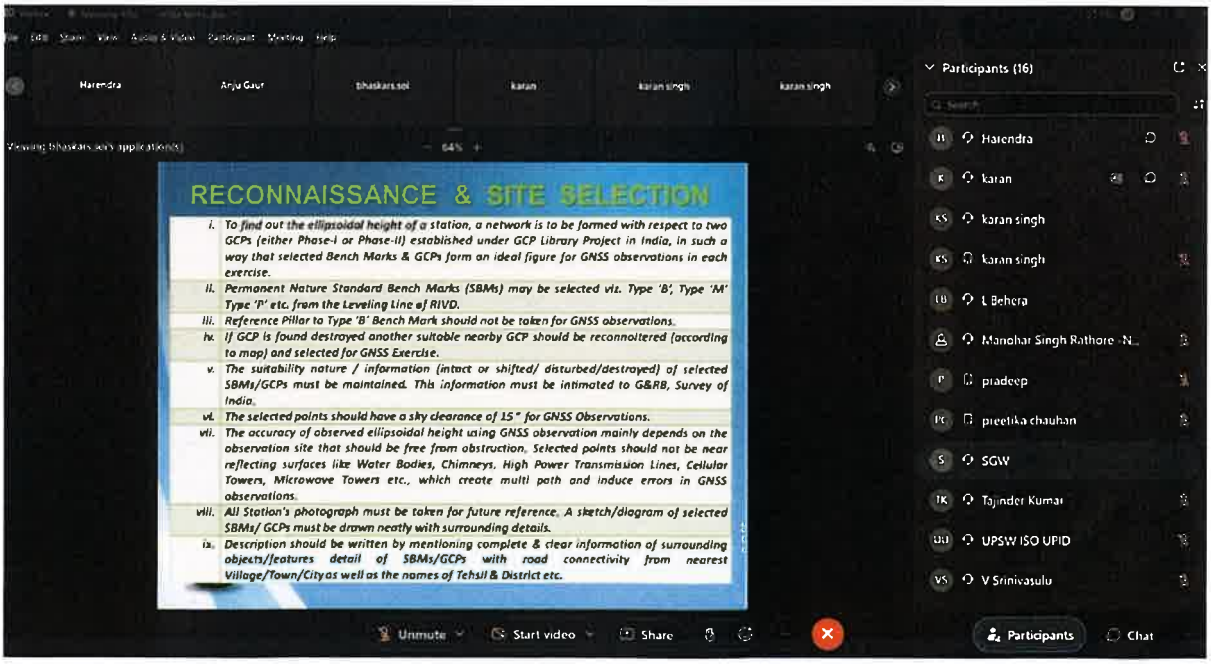
TRAINING GLIMPSES

Snapshots of online training on "Use of CORS Network and Height by Geoid Model"







ABSTRACT OF THE TRAINING

The one day online training on " Use of CORS Network and Height by Geoid Model" was organized at G&RB, Survey of India, Dehradun on 07th June, 2022. The aim of the training was to familiarize the officers from various Implementing Agencies under NHP about the technical aspects and use of CORS and Geoid Model. It includes the general introduction to CORS, use of CORS network to get realtime precise positioning, Gravimeter observation and use of Geoid Model to obtain Orthometric height using GNSS observations. Participants from various Implementing Agencies under NHP participated in this online training.

LECTURE ORGANIZED

SNO	TOPIC	LECTURE BY	DATE
1	Use of CORS Network	Sh. Avanish Kumar, DSS, G&RB	07.06.2022
2	Height by Geoid Model	Sh. Bhaskar Sharma, OS, G&RB	07.06.2022